REMARKS

The specification has been amended to include a reference to the PCT International Application and the Japanese priority applications claimed therein.

Other amendments to the specification are reflected in the enclosed Substitute Specification and marked-up copy thereof.

The claims have been amended to change the phrase "characterized in that" to --wherein-- and to delete all multiple dependencies.

The Office is authorized to charge any underpayment or credit any overpayment to Kenyon & Kenyon's Deposit Account No. 11-0600.

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Respectfully submitted,

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~~DESCRIPTION~~

Water-Cooled Engine and Cylinder Block Thereof

Related Applications:

This is a 371 application of PCT/JP2004/016386 filed on 28 October 2004, claiming priority to Japanese Application No. 2003-373196 filed on 31 October 2003, and No. 2004-183991 filed 22 June 2004, the entire contents of which are incorporated herein by reference.

~~TECHNICAL~~ FIELD OF THE INVENTION

The present invention relates to a water-cooled engine that has a cylinder block assembled with a cylinder head, which cylinder block has a water jacket defined about cylinder bores. The present invention also pertains to a cylinder block used in such a water-cooled engine.

BACKGROUND [[ART]] OF THE INVENTION

In the cylinder block of a water-cooled engine, a water jacket for circulating coolant is defined about cylinder bores. The cylinder block generally consists of an upper cylinder liner portion in which cylinder bores are formed, and a lower crankcase portion that forms a crankcase.

The types of the water jacket in the cylinder block of such a water-cooled engine include an open-deck structure in which the water jacket is open at the top of the cylinder block and a closed-deck structure in which the water jacket is not open at the top of the cylinder block but closed.

Japanese Laid-Open Utility Model No. 62-119450 discloses a cylinder block for a water-cooled engine, having upper and lower parts, or a cylinder liner portion and a crankcase

portion. In the cylinder block of the publication, a water jacket is open to the lower portion of the cylinder liner portion. Therefore, even if a water jacket of the closed deck structure is used, the cylinder block can be molded without using a core. Therefore, a die casting to which sand core is difficult to apply is used can be adopted to mold the cylinder block.

Japanese Laid-Open Patent Publication No. 2002-97997 discloses a cylinder block of a water cooled engine, in which a lower end of a cylinder liner is press fitted to a cylinder main body. This cylinder block is known as a wet liner structure in which the cylinder liner contacts the water jacket.

This publication also discloses a structure in which a circumferential projection is formed on an end of the cylinder liner close to the cylinder head and the projection contacts the cylinder block main body. This structure supports the cylinder liner at its upper and lower ends so that the cylinder liner is firmly secured.

The cylinder block of the above described water-cooled engine has an intricate shape because of the water jacket defined about the cylinder bores. Therefore, casting deficiencies such as blow holes are likely to be formed. Such casting deficiencies degrade the quality. In the die for casting such a cylinder block, a portion for molding the water jacket is extremely thin and difficult to cool. This results in a shortened life of the die. Particularly, in recent years, demands for reduced size and weight of engines and a reduced amount of coolant circulation have resulted in narrower water jackets. Accordingly, the above deficiencies have become obvious.

Although the cylinder block disclosed in Japanese Laid-Open Utility Model No. 62-119450 has separately formed crankcase portion and cylinder liner portion, a narrow and deep groove, which functions as a water jacket, has to be formed in the cylinder liner portion. Therefore, the above described deficiencies are inevitable when casting the cylinder block.

However, these deficiencies can be avoided by adopting a wet liner structure as described in Japanese Laid-Open Patent Publication No. 2002-97997. That is, since the cylinder liner forms a wall surface of the water jacket facing the cylinder, it is possible to form a water jacket without forming a narrow and deep groove in the cylinder block main body.

However, in this type of cylinder block, since the lower end of the cylinder liner is press fitted in the cylinder block main body, the cylinder bores can be deformed. It is thus necessary to finish the cylinder bore wall surfaces after the cylinder liner is assembled.

Further, a cylinder block having a wet liner structure has the following drawbacks. During operation of the engine, the bottom surface of the cylinder head is deformed as if it is lifted by combustion pressure. At this time, the top surface of the cylinder block main body, which is fastened to the cylinder head with bolts, is deformed integrally with the cylinder head bottom surface. However, the cylinder liner is not directly fixed to the cylinder head, and is pressed downward by the head gasket. Therefore, the top surface of the cylinder liner does not follow the deformation of the cylinder head bottom surface, which creates a step between the top surface of the cylinder liner and the top surface of the cylinder block. This degrades the sealing of coolant and combusted gas. Forming a projection at the upper portion of

the cylinder liner limits deformation of the cylinder liner in the circumferential direction relative to the cylinder block main body. However, the projection is not sufficient to permit the top surface of the cylinder liner to follow deformation of the cylinder head bottom surface.

SUMMARY OF THE INVENTION

Accordingly, it is an objective of the present invention to provide a water-cooled engine that facilitates formation of a water jacket about cylinder bores and to provide a cylinder block of the engine.

To achieve the foregoing and other objectives and in accordance with the purpose of the invention, a water cooled engine having a cylinder block and a cylinder head is provided. The cylinder block has a cylinder bore and a water jacket provided about the cylinder bore. The cylinder head is assembled to the cylinder block. The cylinder block is divided at the water jacket into a cylinder liner portion and a cylinder outer wall portion. The cylinder liner portion has a wall defining the cylinder bore. The cylinder outer wall portion surrounds the wall of the cylinder liner portion, thereby defining the water jacket between the cylinder outer wall portion and the wall of the cylinder liner portion. The cylinder liner portion includes an upper deck portion integrally formed with the cylinder liner portion. The upper deck portion contacts the cylinder head assembled to the cylinder block. The cylinder outer wall portion has a top surface that functions as a receiving surface. The receiving surface contacts and supports the upper deck portion.

The present invention also provides a cylinder block of a water-cooled engine. The cylinder block has a cylinder bore and a water jacket provided about the cylinder bore, and is assembled to a cylinder head. The cylinder block is divided

at the water jacket into a cylinder liner portion and a cylinder outer wall portion. The cylinder liner portion has a wall defining the cylinder bore. The cylinder outer wall portion surrounds the wall of the cylinder liner portion, thereby defining the water jacket between the cylinder outer wall portion and the wall of the cylinder liner portion. The cylinder liner portion includes a substantially planar upper deck portion integrally formed with the cylinder liner portion. The upper deck portion forms a top surface of the cylinder block. The cylinder outer wall portion has a top surface that functions as a receiving surface. The receiving surface contacts and supports the upper deck portion.

Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a perspective view illustrating a main body of a water-cooled engine according to one embodiment of the present invention;

Fig. 2(a) is a perspective view illustrating the cylinder block of the embodiment of Fig. 1;

Fig. 2(b) is a side view illustrating the cylinder block of the embodiment of Fig. 1;

Fig. 3 is an exploded perspective view illustrating the cylinder block;

Fig. 4(a) is a perspective view illustrating an inner block of the cylinder block;

Fig. 4(b) is a side view illustrating the inner block of

the cylinder block;

Fig. 5(a) is a perspective view illustrating an outer block of the cylinder block;

Fig. 5(b) is a side view illustrating the outer block of the cylinder block;

Fig. 6 is a cross-sectional view taken along line 6-6 of Fig. 2(b); and

Fig. 7 is a cross-sectional view taken along line 7-7 of Fig. 1.

~~BEST MODE FOR CARRYING OUT THE INVENTION~~ DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A water-cooled engine 1 and a cylinder block 3 of the engine according to one embodiment of the present invention will now be described with reference to drawings.

Fig. 1 is a perspective view illustrating a main body of the water-cooled engine 1 of the present invention. The engine 1 is in-line four cylinders. Generally, the main body of the water-cooled engine 1 consists of a cylinder head 2 and the cylinder block 3. The cylinder head 2 and the cylinder block 3 are fastened to each other with a gasket 4 in between with bolts. Although not illustrated, a head cover is attached to the upper side of the cylinder head 2, and an oil pan is attached to the lower side of the cylinder block 3.

Fig. 2(a) is a perspective view of the cylinder block 3, and Fig. 2(b) is a side view of the cylinder block 3. As shown in these drawings, the cylinder block 3 has four cylinder bores 5 formed in an upper portion. A crankcase portion 31, or a skirt portion of the cylinder block 3, is provided below the cylinder bores 5. The crankcase portion 31, together with the oil pan attached to the lower side, forms a crankcase for accommodating a crankshaft. An upper deck portion 22 is provided at the top portion of the cylinder

block 3. The cylinder head 2 is placed on and contacts the upper deck portion 22.

Fig. 3 is an exploded perspective view of the cylinder block 3. As shown in this drawing, the cylinder block 3 has an inner block 20 and an outer block 30, which are separately formed. Accordingly, a section between the upper deck portion 22 and the crankcase portion 31 is divided into a cylinder liner portion 21 and a cylinder outer wall portion 32 at a portion that functions as a water jacket surrounding the cylinder bores 5. The cylinder liner portion 21 forms a circumferential wall defining the cylinder bores 5, and the outer wall portion 32 forms an outer wall surrounding the water jacket. The cylinder liner portion 21 is formed integrally with the upper deck portion 22, and the cylinder outer wall portion 32 is formed integrally with the crankcase portion 31.

The inner block 20 forming the cylinder liner portion 21 and the upper deck portion 22 is made, for example, of an aluminum alloy or a magnesium alloy and mold to be an integral member through die casting. Like the inner block 20, the outer block 30 forming the crankcase portion 31 and the cylinder outer wall portion 32 is made, for example, of an aluminum alloy or a magnesium alloy and mold to be an integral member through die casting. Reinforcing ribs 3a are formed horizontally and vertically on the outer surface of the crankcase portion 31 and the cylinder outer wall portion 32 of the outer block 30.

Fig. 4(a) is a perspective view of the inner block 20, and Fig. 4(b) is a side view of the inner block 20.

As shown in these drawings, the cylinder liner portion 21 of the inner block 20 has a shape formed by connecting four

cylindrical bodies in series. The inner surface 23 of each cylindrical body form the circumferential wall of one of the cylinder bores 5. The outer surface 24 of the cylindrical bodies form a wall of the water jacket formed about the cylinder bores 5. A projection 25 projecting radially outward from the cylinder bores 5 is formed at the lower end of the cylinder liner portion 21. The inner surfaces 23 of the cylinder liner portions 21, which define the cylinder bores 5, are coated with protective films, for example, of iron through thermal spraying.

The upper deck portion 22 is formed substantially planar at a top portion of the cylinder liner portion 21. The upper deck portion 22 forms a top surface portion of the cylinder block 3. The upper surface of the upper deck portion 22 functions as a mounting surface 26, on which the cylinder head 2 is mounted. During assembly, the bottom of the cylinder head 2 contacts the mounting surface 26. Bolt through holes 27 are formed in the upper deck portion 22. The bolt through holes 27 receive head bolts 7 for fastening the cylinder head 2 and the cylinder block 3 to each other (see Fig 7). Each bolt 7 is not threaded or fixed to the corresponding bolt through hole 27 but is merely passed through the bolt through hole 27. Further, the upper deck portion 22 has through holes such as coolant holes 28, oil holes 29a, and blowby gas holes 29b.

Fig. 5(a) is a perspective view of the outer block 30, and Fig. 5(b) is a side view of the outer block 30.

As shown in these drawings, the crankcase portion 31 has at its upper portion the cylinder outer wall portion 32, which protrudes upward. The cylinder outer wall portion 32 is formed substantially as a loop and has an inner surface 35. The inner surface 35 faces the outer surface 24 of the

cylinder liner portion 21 of the inner block 20. The inner surface 35 of the cylinder outer wall portion 32 forms an outer wall of the water jacket. A step 35a is formed substantially in the middle with respect to the vertical direction (see Fig 3). A section of the inner surface 35 that is below the step 35a is formed to be closer to the outer surface 24 of the cylinder liner portion 21 than the section above the step 35a to the outer surface 24.

A flange 36 protruding radially outward of the cylinder bores 5 is formed at the upper portion of the cylinder outer wall portion 32. The flange 36 is coupled to some of the ribs 3a formed on the outer surface of the cylinder outer wall portion 32, which increases the rigidity. The top surface of the cylinder outer wall portion 32, at which the flange 36 is formed, forms a receiving surface 32a that contacts and supports the upper deck portion 22 of the inner block 20. In this embodiment, the flange 36 is formed at the upper end of the cylinder outer wall portion 32 so that the area of the receiving surface 32a is increased.

Bolt receiving holes 37 are formed in the receiving surface 32a of the cylinder outer wall portion 32. The above described head bolts 7 shown in Fig. 7 are threaded to the bolt receiving holes 37. Further, oil passages 38a, blowby gas passages 38b are formed in the cylinder outer wall portion 32. The passages 38a, 38b are open in the receiving surface 32a. The oil passages 38a return surplus oil from the cylinder head 2 to the oil pan. The blowby gas passages 38b extend from the crankcase into the cylinder head 2, and allow blowby gas to pass therethrough. A coolant port 39 is formed on a side of the cylinder outer wall portion 32. The coolant port 39 permits coolant to flow into and out of the water jacket.

The cylinder liner portion 21 of the inner block 20 is inserted into the cylinder outer wall portion 32 from above. At this time, a clearance exists between the outer surface 24 of the cylinder liner portion 21 and the inner surface 35 of the cylinder outer wall portion 32. The coolant holes 28 formed in the upper deck portion 22 open to the clearance at the lower side of the upper deck portion 22. Also, the openings of the bolt receiving holes 37, the oil passages 38a, and the blowby gas passages 38b formed in the cylinder outer wall portion 32 are aligned with the bolt through holes 27, the oil holes 29a, and the blowby gas holes 29b formed in the upper deck portion 22, respectively.

Fig. 6 is a cross-sectional view illustrating the cylinder block 3 taken along line 6 - 6 of Fig. 2(b), in which the inner block 20 is assembled with the outer block 30.

As shown in this drawing, the cylinder liner portion 21 of the inner block 20 is inserted into the cylinder outer wall portion 32 to a point where the receiving surface 32a of the cylinder outer wall portion 32 contacts the lower surface of the upper deck portion 22. Accordingly, the outer surface 24 of the cylinder liner portion 21, the inner surface 35 of the cylinder outer wall portion 32, and the lower surface of the upper deck portion 22 define a water jacket 6 about the cylinder bores 5.

On the other hand, the outer surface of the projection 25 at the lower end of the cylinder liner portion 21 contacts a lower portion of the inner surface 35 of the cylinder outer wall portion 32. Accordingly, the cylinder liner portion 21 contacts and is supported by the lower portion of the inner surface 35 of the cylinder outer wall portion 32 at the outer wall of the lower portion of the cylinder liner portion 21. That is, in this embodiment, the lower portion of the inner

surface 35 of the cylinder outer wall portion 32 functions as a support portion and a support surface.

Fig. 7 is a cross-sectional view illustrating the main body portion of the water-cooled engine 1 taken along line 7 - 7 of Fig. 1, in which the cylinder block 3 is assembled with the cylinder head 2. As shown in these drawings, the cylinder head 2 is assembled with the cylinder head 2 by fastening the head bolts 7.

The head bolts 7 are inserted through the bolt through holes 27 formed in the upper deck portion 22 of the inner block 20, and threaded to the bolt receiving holes 37 formed in the outer block 30. At this time, the upper deck portion 22 of the inner block 20 is held between the bottom surface 2a of the cylinder head 2 and the receiving surface 32a of the cylinder outer wall portion 32 of the outer block 30. That is, fastening the head bolts 7 applies compression force to the upper deck portion 22 through the bottom surface 2a and the receiving surface 32a. Accordingly, the upper deck portion 22 is fixed.

Although not illustrated, a water jacket, oil passages, and blowby gas passages are formed in the cylinder head 2 and are open at the bottom surface 2a of the cylinder head 2. When the assembly is complete, these openings are aligned with the corresponding openings in the upper deck portion 22, or the coolant holes 28, the oil holes 29a, and the blowby gas holes 29b. The through holes in the upper deck portion 22 connect the passages in the cylinder head 2 with the corresponding passages in the outer block 30.

In this embodiment thus constructed, the inner wall of the water jacket 6 surrounding the cylinder bores 5 is formed on the inner block 20, and the outer wall of the water jacket

is formed on the separate outer block 30. This simplifies the shape of portions of the die that is related to the formation of the water jacket 6. Since the shape of the die is simplified, casting deficiencies such as blow holes are significantly reduced and the life of the die is extended. Accordingly, the formation of the water jacket about the cylinders is facilitated.

In the case where the wall surfaces of the cylinder bores 5 are formed by forming protective films, for example, of iron through thermal spraying, cavities formed by casting deficiencies such as blow holes will remain on the surfaces of the cylinder bores 5. As a result, a clearance exits between the sliding surfaces of each cylinder bore 5 and the corresponding piston ring. This creates drawbacks such as increased consumption of lubricant. Thus, conventionally, prior to forming a protective film through thermal spraying, cavities caused by casting deficiencies must be removed through machining, which increases the manufacturing costs. To the contrary, in this embodiment, since the above described simplification of the die significantly reduces casting deficiencies such as blow holes, the manufacturing costs related to the thermal spraying o the cylinder bore surfaces are reduced.

This embodiment has the following advantages.

(1) The cylinder block 3 has the inner block 20 and the outer block 30, which are separately formed, and the water jacket 6 is defined by the inner wall of the outer block 30 and the outer wall of the inner block 20. This allows the shape of the die to be simplified. Accordingly, casting deficiencies such as blow holes are reduced and the life of the die is extended. Accordingly, the formation of the water jacket about the cylinders is facilitated.

(2) Since the casting deficiencies are reduced, formation of the protective films, for example, of iron on the surfaces of the cylinder bores 5 is facilitated.

(3) Since the outer surface of the projection 25 formed at the lower end of the cylinder liner portion 21 of the inner block 20 are supported by the lower portion of the inner surface 35 of the cylinder outer wall portion 32, the cylinder liner portion 21 is stably fixed.

(4) When assembling the cylinder head 2 with the cylinder block 3, the upper deck portion 22 of the inner block 20 is held between the bottom surface 2a of the cylinder head 2 and the receiving surface 32a of the cylinder outer wall portion 32, and is fixed by fastening the head bolts 7. Thus, the inner block 20 is stably fixed. Also, the upper deck portion 22, the cylinder outer wall portion 32, and the cylinder head 2 are fastened to each other with the head bolts 7. Therefore, even if the bottom surface of the cylinder head 2 is deformed upward by combustion pressure, the contacting surfaces of sealing portions are not separated. The sealing performance therefore does not deteriorate.

(5) Due to the advantages (3) and (4), the rigidity of the cylinder liner portion 21, which is independently formed, is easily maintained.

(6) Since the area of the receiving surface 32a is increased by forming the flange 36 at the top surface portion of the cylinder outer wall portion 32, the upper deck portion 22 is stably fixed.

(7) Since through holes are formed in the upper deck portion 22 to connect fluid passages formed in the cylinder

head 2 with fluid passages formed in the outer block 30, the fluid passages in the cylinder head 2 and the outer block 30 are connected to each other with a simple structure. Also, forming such through holes in the upper deck portion 22 increases the area of the receiving surface 32a. This, in turn, permits the inner block 20 to be stably fixed to the outer block 30.

The above embodiment may be modified as follows.

In the illustrated embodiment, the inner block 20 and the outer block 30 are made of an aluminum alloy or a magnesium alloy. However, the material may be arbitrarily changed. For example, one or both of the inner block 20 and the outer block 30 may be made of cast iron. If the overall mechanical strength of the cylinder block 3 is ensured by the outer block 30, the inner block 20 may be made of a material the strength of which is not easily improved. For example, ceramics or sintered metal may be used. Also, the outer block 30, which is not directly exposed to combusted gas in the cylinders, may be made of material having a relatively low heat resistance. For example, resin may be used.

In the illustrated embodiment, the inner block 20 and the outer block 30 are formed through die casting. However, the blocks 20, 30 may be formed through method other than die casting.

In the illustrated embodiment, the protective films are formed on the wall surfaces of the cylinder bores 5. However, such treatment does not need to be applied. For example, if separately formed cylinder liners may be attached to the inner surfaces 23 of the cylinder liner portion 21 or if the inner block 20 is made of a material having a sufficient wear resistance, the base material may be used to form the surfaces

of the cylinder bores 5.

If the sealing property in the contacting surfaces of the upper deck portion 22 and the receiving surface 32a and the sealing property in the contacting surfaces of the outer circumferential surface of the projection 25 and the lower portion of the inner surface 35 are insufficient, a sealing structure such as an application of a sealing agent or sealing member may be provided at those contacting surfaces.

In the illustrated embodiment, the projection 25 is formed at the lower portion of the cylinder liner portion 21, and the outer circumference surface of the projection 25 contacts the inner surface 35 of the cylinder outer wall portion 32 to support the cylinder liner portion 21 from below. A projection like the projection 25 may be formed on the inner surface 35 of the cylinder outer wall portion 32. In this case also, the cylinder liner 21 is supported from below. This stably fixes the cylinder liner portion 21.

A supporting surface for supporting the lower end of the cylinder liner portion 21 may be integrally formed with the cylinder outer wall portion 32, and the cylinder liner portion 21 may be supported by the supporting surface from below. In this case also, the cylinder liner portion 21 is stably fixed.

If the rigidity of the cylinder liner portion 21 is secured by fixing the upper deck portion 22, a supporting portion for supporting the lower portion of the cylinder liner 21 does not need to be formed in the cylinder outer wall portion 32. In this case, however, a sealing structure needs to be provided to prevent coolant from leaking from the water jacket 6 at the lower portion of the cylinder liner portion 21.

In the illustrated embodiment, the crankcase portion 31

and the cylinder outer wall portion 32 are integrated to form the outer block 30. However, the crankcase portion 31 and the cylinder outer wall portion 32 may be formed separately. In this case, the cylinder block 3 includes separately formed three pieces, which are the inner block 20, the cylinder outer wall portion 32, and the crankcase portion 31. This structure increases the number of the components and the number of the dies, but is advantageous in a case where the integrally formed crankcase portion 31 and the cylinder outer wall portion 32 have complicated shapes and are thus difficult to mold.

In the illustrated embodiment, the present invention is applied to the water-cooled engine having in-line four cylinders. However, the present invention may be applied to any type of water-cooled engine as long as a cylinder block in which a water jacket is defined about cylinder bores is assembled with a cylinder head.